Article

Gerontology & Geriatric Medicine
Volume 2: 1–9
© The Author(s) 2015
DOI: 10.1177/2333721415623495
ggm.sagepub.com
SAGE

Association of Co-Existing Impairments in Cognition and Self-Rated Vision and Hearing With Health Outcomes in Older Adults

Phillip L. Liu, MD, MBA[1,2], Harvey Jay Cohen, MD[1,2,4], Gerda G. Fillenbaum, PhD[1], Bruce M. Burchett, PhD[1], and Heather E. Whitson, MD, MHS[1,2,3,4]

Abstract

Objective: The objective of this study was to assess the relationship of disability (activities of daily living [ADL] and instrumental ADL [IADL]), self-rated health (SRH), and 6-year mortality with co-existing impairments in vision (self-rated), hearing (self-rated), and/or cognition (Short Portable Mental Status Questionnaire) in older adults. **Method:** The study sample comprised of 3,871 participants from the North Carolina Established Populations for Epidemiologic Studies of the Elderly study (NC EPESE). **Results:** Persons with all three impairments had increased odds of ADL/IADL disability and low SRH. Participants with combined visual and cognitive impairments had increased odds of mortality. Whereas sensory impairments were associated with poor SRH, cognitive impairment was not unless both sensory impairments were present. **Conclusion:** Co-existent sensory and cognitive impairments were associated with higher risk of impaired functional status. Self-rated auditory impairment alone was not associated with higher odds of death, but mortality was linked to visual and, particularly, cognitive impairment, alone or combined.

Keywords

sensory impairment, disability, cognition, multi-morbidity, health outcome

Manuscript received: August 30, 2015; **final revision received:** November 20, 2015; **accepted:** November 24, 2015.

Introduction

As the majority of older adults have multiple co-existing chronic diseases, attention to multiple chronic conditions (MCC) has become a central issue within geriatric care (Marengoni et al., 2011; Parekh, Kronick, & Tavenner, 2014). Recent studies have demonstrated the consequences of MCC on functional status, quality of life, and death (Marengoni et al., 2011; Whitson et al., 2007). However, due in part to the wide variety of possible combinations of MCC, questions remain about the degree of impact that co-existing conditions have on health outcomes. A better understanding of how specific, common, age-related conditions relate to health outcomes is necessary to guide efforts at improving care and maximizing health for this population.

Sensory impairments and cognitive impairment are not only common with aging and frequently co-exist but are also believed to share common etiologies (Whitson et al., 2007). Mitochondrial malfunction has been proposed as a common mechanism underlying age-related sensory and cognitive declines (Van Eyken, Van Camp, & Van Laer, 2007). These impairments also share common risk factors for neurodegeneration, including diabetes, vascular disease, and oxidative stress (Cheung & Wong, 2008; Emerit, Edeas, & Bricaire, 2004). Cognitive, auditory, and visual impairments have been shown to negatively affect individuals' quality of life, individually and in pairs (Logsdon, Gibbons, McCurry, & Teri, 2002; Mulrow et al., 1990; Uhlmann, Larson, Koepsell, Rees, & Duckert, 1991). Studies have demonstrated a relationship between visual impairment, auditory impairment, and combined visual and auditory impairment with cognitive impairment (Heyl & Wahl, 2012;

[1]Center for the Study of Aging and Human Development, Duke University
[2]Department of Medicine, Duke University, Durham, NC
[3]Department of Ophthalmology, Duke University, Durham, NC
[4]Durham VA Medical Center, Geriatrics Research Education and Clinical Center, Durham, NC

Corresponding Author:
Phillip L. Liu, Duke University Medical Center 3003, Durham, NC 27710, USA.
Email: Phillip.Liu@duke.edu

M. Y. Lin et al., 2004; F. R. Lin et al., 2013; Reyes-Ortiz et al., 2005).

Visual, auditory, and cognitive impairments are independent risk factors for disability in activities of daily living (ADLs), instrumental activities of daily living (IADLs), and self-rated health (SRH; Bess, Lichtenstein, Logan, Burger, & Nelson, 1989; Cacciatore et al., 2004; Chia et al., 2006; Chia et al., 2007; Jacobs, Hammerman-Rozenberg, Maaravi, Cohen, & Stessman, 2005; Kim et al., 2005; McGuire, Ford, & Ajani, 2006; Pedone et al., 2005; Peres, Verret, Alioum, & Barberger-Gateau, 2005; Rudberg, Furner, Dunn, & Cassel, 1993; Salive et al., 1994; Strawbridge, Wallhagen, Shema, & Kaplan, 2000; Swanson & McGwin, 2004; West et al., 1997). In particular, SRH is an important indicator for quality of life from the subjects' perspective, as well as its demonstrated relationship with multiple co-morbidities in diverse populations (Sullivan, 2003; Whitson, Malhotra, Chan, Matchar, & Ostbye, 2012). In the present study, we included consideration of mortality as an additional dependent variable not only for its clinical relevance but also because the relationship between all co-existing sensory and cognitive impairments, and the dependent variables defined in this study has not hitherto been published (Fisher et al., 2014).

In previous work, our group described the combined effect of visual and cognitive impairment on disability status in older adults. However, there is limited research that has studied the association between functional well-being and the various combinations of visual, hearing, and cognitive impairments. The aim of the current study was to determine how various combinations of visual, auditory, and cognitive impairments relate to disability, SRH, and death in a well-defined cohort of community-dwelling older adults.

Method

Study Population

This study analyzed data from the North Carolina Established Populations for Epidemiologic Studies of the Elderly (NC EPESE) project, as part of a multi-center, collaborative epidemiologic investigation of change over time in the health status, physical, social, and cognitive functioning, and health service use of persons 65 years of age and older. A four-stage sampling design was used to obtain a probability sample of participants aged 65 years or older living in households in the five-county survey area. In-person baseline information was obtained between January 1986 and June 1987 from 4,162 participants, 80% of those contacted. Participants were re-interviewed annually for 6 years, and then again at 10 years post-baseline (Cornoni-Huntley et al., 1993). Survival status was tracked using the national death index.

For the current study, all 162 participants interviewed by proxy were excluded due to significant cognitive impairment that called into question the accuracy of their responses. Participants were further excluded if baseline information was missing on any variable required in the analysis, resulting in an analysis sample of 3,871 participants. The institutional review board of Duke University Medical Center approved this study, and written consent was obtained from all participants.

Independent Variables

Visual impairment was assessed based on two self-reported questions on whether subjects could recognize a friend across the street (distance vision) or read ordinary newspaper print (near vision) using their best corrected vision with either glasses or contact lenses. If the answer to either question was negative, then the subject was considered visually impaired. Previous studies have found that response to these two questions is correlated with measured visual acuity (Hart, Chakravarthy, Stevenson, & Jamison, 1999).

Auditory impairment was assessed based on three self-reported questions (a-c) and one question (d) based on the observation of the interviewer: (a) Have you ever worn a hearing aid? (b) Can you hear and understand a person without seeing his or her face? (c) How often do you wear a hearing aid (1 = *never*, 2 = *occasionally*, 3 = *frequently*, 4 = *always*)? (d) Did respondent have difficulty hearing or was deaf (1 = *no*, 2 = *some*, 3 = *deaf*)? Auditory impairment was considered present if at least one of the following responses was present, regardless of whether conflicting responses were given: "yes" to (a), "no" to (b), or any number greater than 1 to (c), or (d). This constructed definition of auditory impairment is expected to capture hearing loss that was clinically noticeable to the participant, caregiver, provider, and/or interviewer (i.e., loss important to the sample member), but not necessarily hearing loss identifiable by auditory assessment, which could not be performed in this epidemiological survey. Previous studies support the use of self-reported data to identify auditory impairments (Davanipour, Lu, Lichtenstein, & Markides, 2000).

Cognitive impairment was assessed using the 10-item Short Portable Mental Status Questionnaire (SPMSQ), which has established validity and reliability (Pfeiffer, 1975). Consistent with previous work, cognitive impairment was defined as four or more errors on the SPMSQ (Whitson et al., 2007). Refusal or "don't know" responses were counted as errors.

Dependent Variables

The dependent variables included level of functioning in ADL and IADL, SRH, and death by Year 6. Functional status was assessed by five Katz ADL items (bathing, dressing, transferring from bed to chair, using the toilet, and feeding self), and five Older Americans Resources and Services (OARS) IADL items (travel out of walking distance, shopping, preparing meals, doing housework, and handling finances; Fillenbaum, 1985; Katz, Downs, Cash, & Grotz, 1970). The five-item IADL measure was chosen in preference to the seven-item measure, which includes tasks with a significant cognitive component, to minimize association with the SPMSQ. The two excluded items include taking own medication and telephone use. In agreement with previous studies, ADL disability was defined by self-reported inability to perform at least one ADL task, and similarly for IADL (Melzer, Izmirlian, Leveille, & Guralnik, 2001; Mendes de Leon et al., 1995; Whitson et al., 2007).

SRH was reported by participants as poor, fair, good, or excellent. These categories were dichotomized as poor or fair versus good or excellent, to reflect overall health status (Idler & Benyamini, 1997). Previous studies have found SRH to be a reliable predictor of poor health status and outcomes (McGee, Liao, Cao, & Cooper, 1999).

Survival status was obtained from the national death index, and dichotomized as dead or alive 6 years after baseline.

Covariates

The following control variables were included due to their known association with disability, SRH status, and death: age, sex, race, education, marital status, body mass index, current or past history of smoking, depression, and five chronic diseases. Race was determined by self-report, and dichotomized as Black or non-Black (<1% of participants were neither Black nor White). Age, education, and body mass index (kg/m^2) were analyzed as continuous variables and sex, race (Black vs. all others), and marital status (married vs. all others) as dichotomous variables. Smoking status (never smoked vs. currently smoke or ever smoked) was self-reported. Depressive symptomatology was determined by a modified Center for Epidemiologic Studies Depression Scale and defined by a score of greater than 8 (Blazer, Burchett, Service, & George, 1991). Disease conditions (cancer excluding skin cancer, stroke, diabetes, hypertension, and myocardial infarction) were individually assessed based on self-report of physician-diagnosed condition. A health index score (weighted sum of disease conditions; Fillenbaum, Leiss, Pieper, & Cohen, 1998), was developed to reflect a participant's health burden.

Analysis

Descriptive statistics were used to provide baseline information on the cohort, including information on sample sizes for all combinations of visual, auditory, and cognitive impairment. Logistic regression was used to examine the association of visual, auditory, and cognitive impairment, and each of their possible combinations, with ADL disability, IADL disability, and SRH at baseline, and with death by Year 6, using the "no impairment" group as the referent, and adjusting for the covariates described above. We examined only the cross-sectional relationship for the dependent variables ADL disability, IADL disability, and SRH because older adults frequently transition between spectrums of these health states, meaning that the true longitudinal trajectory of these outcomes is poorly captured by annual or triennial intervals of assessment (Thielke & Diehr, 2012). Longitudinal data, on the contrary, was included for mortality by Year 6.

A forest plot was utilized to graphically display odds ratios with 95% confidence intervals across all combinations of impairment groups relative to death by Year 6.

All statistical analyses were performed using SAS statistical software Version 9.0 (SAS Institute, Inc., Cary, NC).

Results

Table 1 summarizes baseline characteristics of the sample. ADL disability was present for 384 participants (9.9%), IADL disability for 1,146 participants (29.6%), and fair/poor SRH for 1,805 participants (46.6%). The majority of the sample (n = 2,330; 60.2%) had no visual, auditory, or cognitive impairment. Visual, auditory, and cognitive impairments alone were reported by 331 participants (8.6%), 564 participants (14.6%), and 208 participants (5.4%), respectively. Both visual and auditory impairments were reported by 183 participants (4.7%), visual and cognitive impairments by 69 participants (1.8%), and auditory and cognitive impairments by 99 participants (2.6%). Impairments in all three areas were reported by 87 participants (2.3%). By 6 years after baseline, 1,115 participants (28.8%) had died.

Disability

Table 2, column 1 reflects the relationship with ADL disability of the various combinations of impairment relative to the totally unimpaired control group. All combinations of impairment, with the exception of the auditory impairment alone group, had significantly increased odds (range = 1.99-4.99) of ADL disability, but while point estimates were higher for the dual as compared with the single impairment groups, the differences were not statistically significant. The combined visual, auditory, and cognitive impairment group had the greatest odds of association with ADL disability.

Table 2, column 2 summarizes information on the relationship between single and co-existing visual, auditory, and cognitive impairment groups with IADL disability, relative to the control group without sensory or cognitive impairments. All combinations of impairment groups were associated with significantly greater odds of IADL disability, ranging from 1.50 to 11.09. Among the three single impairment groups, the greatest odds of disability were seen in the cognitive impairment and visual impairment groups. Combined visual/cognitive impairment was associated with the greatest odds of all combinations of impairments, with a point estimate that

Table 1. Baseline Characteristics of Study Cohort Based on VI, AI, and CI Status.

	Total population (*N* = 3,871)	No impairment (*n* = 2,330)	VI only (*n* = 331)	AI only (*n* = 564)	CI only (*n* = 208)	VI and AI (*n* = 183)	VI and CI (*n* = 69)	AI and CI (*n* = 99)	VI, AI, and CI (*n* = 87)
Age, *M*	73.3	72.0	73.4	74.0	75.5	77.6	75.2	78.6	78.7
Female, %	64.9	66.2	74.9	55.3	61.5	63.4	62.3	63.6	69.0
Black, %	53.8	50.6	61.6	43.8	80.8	50.3	81.2	70.7	74.7
Education, mean years	8.6	9.4	7.7	8.7	5.4	7.8	5.1	6.2	4.9
Married, %	38.7	42.8	29.9	42.9	22.1	23.5	26.1	24.2	32.2
BMI, *M*	26.0	26.2	26.1	26.0	25.5	25.1	26.6	24.6	25.1
Smoker (current or past), %	44.7	45.2	44.4	48.8	41.4	41.0	43.5	34.3	33.3
Depression, %	9.4	6.9	16.6	6.2	13.0	18.0	18.8	21.2	21.8
Self-reported morbidities									
Cancer, excluding skin, %	11.4	11.5	12.1	11.7	10.1	14.2	4.4	6.1	13.8
Stroke, %	7.5	5.8	13.9	6.4	9.1	11.5	10.1	10.1	21.8
Diabetes, %	20.2	19.1	23.3	17.0	20.2	26.2	29.0	24.2	33.3
Hypertension, %	57.6	56.1	69.2	55.5	56.7	56.3	71.0	53.5	63.2
Myocardial infarction, %	15.1	13.6	19.2	15.3	11.1	24.0	17.4	17.2	25.3

Note. Cohort described using means or percentages (as indicated). A health index (sum of chronic health conditions) was created to reflect a participant's health burden. VI = visual impairment; AI = auditory impairment; CI = cognitive impairment; BMI = body mass index.

Table 2. The Association of All Combinations of Visual, Auditory, and Cognitive Impairment With Disability and Self-Rated Health (*N* = 3,871).

Cognitive/sensory impairment category	ADL disability OR (95% CI)	IADL disability OR (95% CI)	Low SRH OR (95% CI)
Vision impairment alone (*n* = 331)	1.99 [1.38, 2.87]	3.02 [2.33, 3.90]	2.02 [1.57, 2.61]
Auditory impairment alone (*n* = 564)	1.23 [0.86, 1.76]	1.50 [1.20, 1.89]	1.23 [1.01, 1.49]
Cognitive impairment alone (*n* = 208)	2.20 [1.40, 3.46]	3.25 [2.36, 4.46]	0.95 [0.70, 1.29]
Vision and auditory (*n* = 183)	2.44 [1.58, 3.74]	6.40 [4.51, 9.07]	2.22 [1.59, 3.11]
Vision and cognitive (*n* = 69)	2.62 [1.34, 5.12]	11.09 [6.01, 20.45]	1.62 [0.96, 2.74]
Auditory and cognitive (*n* = 99)	2.73 [1.56, 4.79]	4.74 [2.99, 7.50]	1.17 [0.76, 1.82]
Vision, auditory, and cognitive impairments (*n* = 87)	4.99 [2.95, 8.44]	10.39 [5.67, 19.05]	2.81 [1.64, 4.82]

Note. All analyses were adjusted for age, sex, race, education, marital status, body mass index, history of smoking, depression, and a health index (sum of chronic health conditions). Instrumental activities of daily living (IADL) disability was assessed by analyzing the 1,146 participants with IADL disability at baseline as the dependent variable. Activities of daily living (ADL) disability was assessed by analyzing the 384 participants with ADL disability at baseline as the dependent variable. Self-rated health (SRH) was assessed by analyzing the 959 participants with poor or low SRH at baseline as the dependent variable. All dependent variables were analyzed relative to the control group without visual, auditory, or cognitive impairment. ADL—assessed as inability to perform any of the following activities: bathing, dressing, transferring from bed to chair, using the toilet, and feeding self. IADL—assessed as inability to perform any of the following activities: travel out of walking distance, shopping, preparing meals, doing housework, and handling finances; SRH: dichotomized as poor/fair versus good/excellent.
OR = odds ratio; CI = confidence interval.

exceeded the odds of IADL disability for the combined visual, auditory, and cognitive impairment group.

SRH

Table 2, column 3 summarizes the relationship of visual, auditory, and cognitive impairment with fair or poor SRH relative to the control group without sensory or cognitive impairment. Statistically significant odds ratios were found for visual impairment alone, auditory impairment alone, visual and auditory impairment, and visual, auditory and cognitive impairment (odds ratios = 1.23-2.81). The three impairment groups with the greatest point estimates all included visual impairment.

Death

Figure 1 summarizes the relationship of visual, auditory, and cognitive impairment with death 6 years after baseline, relative to the control group without sensory or cognitive impairments. All groups, with the exception of auditory impairment alone, were associated with statistically

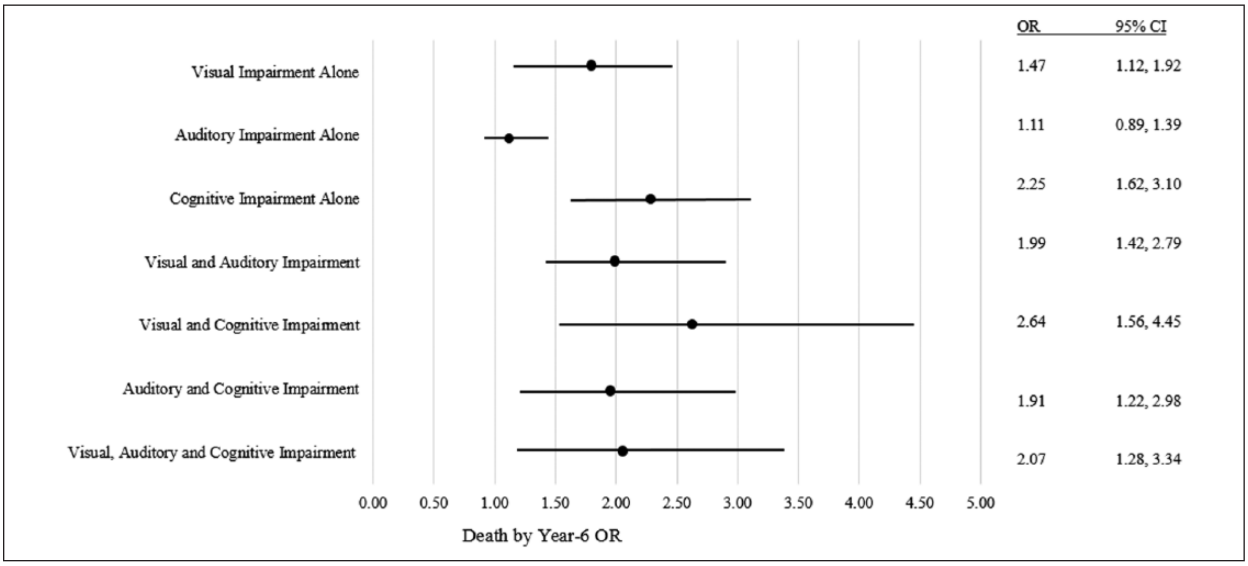

Figure 1. The association of all combinations of visual, auditory, and cognitive impairments with death within 6 years of baseline.
Note. All analyses were adjusted for age, sex, race, education, marital status, body mass index, history of smoking, depression, and a health index score that reflects self-reported disease burden. Death by Year 6 was a dependent variable in logistic regression models analyzed by the forest plot relative to the control group without visual, auditory, or cognitive impairment. OR = odds ratio; CI = confidence interval.

significant odds ratios ranging from 1.47 to 2.64. The three greatest point estimate values all included cognitive impairment, and these had overlapping 95% confidence intervals. The cognitive and visual impairment group was associated with the greatest odds ratio among all combinations of impairment groups.

Vision Impairment

Of the 670 subjects with visual impairment, 333 (49.7%) were farsighted only, 143 (21.3%) were nearsighted only, and 194 (28.9%) were both near- and farsighted. Post hoc analyses confirmed that near-sightedness and far-sightedness were each significantly and independently associated with the four dependent variables (ADL disability, IADL disability, poor SRH, and mortality at 6 years).

Discussion

We assessed the relationship of common, frequently co-existing, sensory and cognitive impairments with various health states and found that particular combinations of visual, auditory, and cognitive impairments relate in distinct ways to different types of disability, SRH, and death. While visual, auditory, and cognitive impairments were related to the health states we studied, their co-existing relationships varied across different dependent variables, and the magnitudes of their odds ratios did not always increase incrementally as the number of impairments accumulated. Our previous study demonstrated that co-existing visual and cognitive impairments are associated with higher risk of disability (Whitson et al., 2007). Our current study adds new insight: particular combinations of sensory and cognitive deficits, rather than the number of deficits, are associated to different degrees with several important domains of health (independence, survival, and patient perceived health).

ADL and IADL disabilities were particularly associated with visual and cognitive impairment, but less strongly related to auditory impairment in our sample. A previous study by Rudberg et al. (1993) suggested no relationship between auditory impairment and ADL disability, whereas a study by Chen, Genther, Betz, and Lin (2014) showed auditory impairment to be associated with greater disability. The discrepancy may be partly explained by differences in the methods used to define hearing impairment across the different studies. For example, the Chen study assessed hearing with pure tone audiometry, whereas our definition of hearing impairment was based on responses from participants or interviewers (Chen et al., 2014; Rudberg et al., 1993). Results from the current study highlight that co-existing sensory and cognitive impairments are associated with higher odds of disability, as compared with associations with sensory or cognitive impairment alone, a finding that is consistent with our group's previous studies but now further incorporates the role of auditory impairment on health outcomes (Whitson et al., 2007; Whitson et al., 2012).

Several explanations could account for the fact that both ADL and IADL disability seemed to be more strongly linked to vision and cognition than to hearing ability. First, because ADL disabilities represent deficits in basic functions, ADL disability may be more likely to exist in the presence of overall increased chronic disease burden, which may in turn be associated with a higher number of cognitive and sensory impairments. In the current study, information on the severity of auditory impairment was not available, which could have contributed to our observation of a statistically nonsignificant relationship between auditory impairment alone and ADL disability. Second, the specific IADL functions assessed in this study are more dependent on visual and cognitive status than on auditory status. For example, ability to manage finances and prepare meals requires proper vision and executive decision-making capabilities, and less critically requires proper auditory function.

Low or poor SRH was significantly related to visual impairment either alone or as a co-existing condition, with odds ratios ranging from 2.02 to 2.81. This observed relationship is supported by previous studies that suggested low visual acuity is associated with reduced quality of life, depression, and higher rates of attempted suicide. In the current study, visual impairment was similarly likely to be associated with low SRH, regardless of whether the visual impairment was accompanied by auditory and/or cognitive impairments. Cognitive impairment was only significantly associated with low SRH when it was accompanied by both visual and auditory impairments. This finding suggests that cognitive impairment may be associated with differences in insight on self-perceived illness ratings (Johnson, Rovner, & Haller, 2014; Yeung et al., 2015).

Death by Year 6 was significantly associated with visual and cognitive impairments, with higher odds ratios associated with cumulative impairments. Previous studies focused on visual impairment, both self-rated and measured via Snellen chart, have demonstrated significant association with mortality in the older adult population (Cacciatore et al., 2004; Jacobs et al., 2005; Thompson, Gibson, & Jagger, 1989). Similarly, a study by Wu et al. (2014) demonstrated that poor cognition measured by the SPMSQ is associated with higher risk for mortality (Wu et al., 2014). This finding is supported by a systematic literature review completed by Dewey and Saz (2001), which reported evidence for a significant relationship between cognitive impairment or dementia and mortality (Dewey & Saz, 2001). Whereas subjects with severe cognitive impairment that required interviews by proxy were excluded in our study, Dewey and Saz found that mortality also correlated with the severity of impairment.

The relationship between auditory impairment and mortality appears to depend on the number of years of follow-up, the particular sub-population studied, and the method used to define auditory impairment. For example, studies with 5 to 6 years of follow-up demonstrated increased odds of mortality, and Appollonio, Carabellese, Magni, Frattola, and Trabucchi (1995) showed that the overall increased mortality risk was only found for men (Appollonio et al., 1995). Studies focused on 1-year follow-up did not demonstrate any significant associations (Fisher et al., 2014; Genther et al., 2015; Karpa et al., 2010; Laforge, Spector, & Sternberg, 1992). Differences in findings between our study and prior studies may reflect different study designs, including our use of self-report as opposed to clinically assessed auditory impairments, as were used by Appollonio and colleagues and Genther and colleagues.

ADL and IADL disabilities are high-cost outcomes that require significant utilization of health care services as well as family and societal resources. Although sensory and cognitive impairments are not immediately life-threatening conditions, they are markers for disability and vulnerability, and may need to be identified early to maximize the potential impact of preventive or remedial interventions. These impairments are linked to serious and costly consequences for patients, payers, and the health system, often even more so when they co-exist. Health system models need to be prepared to accommodate multiple impairments as well as the psychosocial needs of patients with MCC. Creating protocols and incentives for outpatient clinicians to routinely screen for sensory and cognitive impairments may improve early detection and enable specialist referrals. Given constraints on clinicians' time when managing people with MCC, there has been growing interest in developing screening tools for cognition and sensory deficits that utilize telehealth platforms (Fried, Tinetti, & Iannone, 2011; Ostbye et al., 2005). Better detection of the impairments is a first step toward interventions that may reduce progression of symptoms or identify reversible causes (e.g., cataracts, refractive errors, cerumen impaction, medications affecting cognition). Even when impairments are irreversible, rehabilitative services may reduce their impact on quality of life and independence. Our results indicate that integrated rehabilitative services may be particularly valuable for people living with combinations of impairments.

This research highlights the key combinations of sensory and cognitive impairments that are particularly strongly associated with health outcomes of interest. For example, in patients with existing cognitive impairment, preventive health measures to protect patients from visual deterioration may improve outcomes, as the co-existing pair is associated with significantly worse IADL functions. This analysis focused on the adverse health states. Further research is needed to better define the relationship between the impairments studied here and health care utilization and cost. In addition, future prospective research, with frequent re-assessment of key variables, is needed to understand the relationship between changes in cognitive or sensory status and functional independence over time. Considering that disability is a dynamic variable, which may remit and recur more than once in a year (the time period between disability assessments in the NC EPESE data), future longitudinal research in this area should include more frequent characterizations of cognitive, sensory, and disability status (Hardy, Dubin, Holford, & Gill, 2005).

Several limitations of this study may affect the analysis and evaluation of the results. First, visual and auditory impairments were assessed by self-report. Although responses to these questions have been correlated with actual measured acuity, validity has not been evaluated in the North Carolina EPESE population. At 17%, this study likely underestimated the prevalence of auditory impairment in older adults, as compared with the prevalence estimates of 45% when hearing loss is assessed with audiometry equipment (Cruickshanks et al., 1998). Due to the self-reported nature of visual and auditory impairments, this study is intended to assess only the association between our independent and dependent variables, and not to estimate the prevalence of visual or auditory impairments precisely. While our findings regarding the impact of self-perceived hearing and vision loss are intriguing, this study highlights a need for investment in surveillance and population studies with validated measures of both hearing and vision. Second, the causes, severity, and reversibility of visual, auditory, and cognitive impairment are not necessarily clear. Third, the data were collected in the 1980s, so recent health trends (such as obesity and extension of average life expectancy) may influence the prevalence of the variables studied. Although present-day prevalence may differ, our primary research question focuses on relationships between variables, which should be minimally affected by changes in prevalence (Bromfield et al., 2014; King, Aubert, & Herman, 1998). Fourth, our analytic approach allowed us to examine seven unique impairment status categories. While central to accomplishing our aim, some of these impairment categories had relatively small numbers (e.g., n = 69 in the Visual and Cognitive Impairment group), which affects the precision of our estimates and potentially misrepresents relationships between independent and dependent variables. Fifth, given the constraints of the EPESE questionnaire, we were unable to control for other important medical variables and their severity that may relate to the study outcome. Sixth, given the observational nature of this study, there always exists the possibility of unknown and unmeasured confounding effects between dependent and independent variables. These limitations are balanced, to some degree, by the fact that the NC EPESE offers an opportunity to study a large, diverse population and is known for high data integrity.

Authors' Note

The content of this publication is solely the responsibility of the authors and does not necessarily reflect the reviews or policies of the U.S. Department of Health and Human Services, the National Institutes of Health, or the National Institute on Aging. The sponsors had no role in the concept, design, or conduct of this study or the preparation of the manuscript.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The data upon which this publication was based were obtained pursuant to Contract Number N01-AG12102 with the National Institute on Aging, in support of the Established Populations for Epidemiologic Studies of the Elderly (Duke). Additional support was provided by Award Number P30AG028716 (Duke Pepper Center) from the National Institute on Aging. Dr. Whitson is supported by the National Institute on Aging (R01AG043438, R24AG045050) and the Alzheimer's Association.

References

Appollonio, I., Carabellese, C., Magni, E., Frattola, L., & Trabucchi, M. (1995). Sensory impairments and mortality in an elderly community population: A six-year follow-up study. *Age and Ageing*, *24*, 30-36.

Bess, F. H., Lichtenstein, M. J., Logan, S. A., Burger, M. C., & Nelson, E. (1989). Hearing impairment as a determinant of function in the elderly. *Journal of the American Geriatrics Society*, *37*, 123-128.

Blazer, D., Burchett, B., Service, C., & George, L. K. (1991). The association of age and depression among the elderly: An epidemiologic exploration. *Journal of Gerontology*, *46*(6), M210-M215.

Bromfield, S. G., Bowling, C. B., Tanner, R. M., Peralta, C. A., Odden, M. C., Oparil, S., & Muntner, P. (2014). Trends in hypertension prevalence, awareness, treatment, and control among US adults 80 years and older, 1988-2010. *The Journal of Clinical Hypertension (Greenwich)*, *16*, 270-276. doi:10.1111/jch.12281

Cacciatore, F., Abete, P., Maggi, S., Luchetti, G., Calabrese, C., Viati, L., . . . Rengo, F. (2004). Disability and 6-year mortality in elderly population: Role of visual impairment. *Aging Clinical and Experimental Research*, *16*, 382-388.

Chen, D. S., Genther, D. J., Betz, J., & Lin, F. R. (2014). Association between hearing impairment and self-reported difficulty in physical functioning. *Journal of the American Geriatrics Society*, *62*, 850-856. doi:10.1111/jgs.12800

Cheung, N., & Wong, T. Y. (2008). Diabetic retinopathy and systemic vascular complications. *Progress in Retinal and Eye Research*, *27*, 161-176. doi:10.1016/j.preteyeres.2007.12.001

Chia, E. M., Mitchell, P., Rochtchina, E., Foran, S., Golding, M., & Wang, J. J. (2006). Association between vision and hearing impairments and their combined effects on quality of life. *Archives of Ophthalmology*, *124*, 1465-1470. doi:10.1001/archopht.124.10.1465

Chia, E. M., Wang, J. J., Rochtchina, E., Cumming, R. R., Newall, P., & Mitchell, P. (2007). Hearing impairment and health-related quality of life: The Blue Mountains Hearing Study. *Ear and Hearing*, *28*, 187-195. doi:10.1097/AUD.0b013e31803126b6

Cornoni-Huntley, J., Ostfeld, A. M., Taylor, J. O., Wallace, R. B., Blazer, D., Berkman, L. F., . . . Korper, S. P. (1993). Established Populations for Epidemiologic Studies of the Elderly: Study design and methodology. *Aging Clinical and Experimental Research (Milano)*, *5*, 27-37.

Cruickshanks, K. J., Wiley, T. L., Tweed, T. S., Klein, B. E., Klein, R., Mares-Perlman, J. A., & Nondahl, D. M. (1998). Prevalence of hearing loss in older adults in Beaver Dam, Wisconsin: The Epidemiology of Hearing Loss Study. *American Journal of Epidemiology*, *148*, 879-886.

Davanipour, Z., Lu, N. M., Lichtenstein, M., & Markides, K. S. (2000). Hearing problems in Mexican American elderly. *American Journal of Otolaryngology*, *21*, 168-172.

Dewey, M. E., & Saz, P. (2001). Dementia, cognitive impairment and mortality in persons aged 65 and over living in the community: A systematic review of the literature. *International Journal of Geriatric Psychiatry*, *16*, 751-761.

Emerit, J., Edeas, M., & Bricaire, F. (2004). Neurodegenerative diseases and oxidative stress. *Biomedicine & Pharmacotherapy*, *58*, 39-46.

Fillenbaum, G. G. (1985). Screening the elderly: A brief instrumental activities of daily living measure. *Journal of the American Geriatrics Society*, *33*, 698-706.

Fillenbaum, G. G., Leiss, J. K., Pieper, C. F., & Cohen, H. J. (1998). Developing a summary measure of medical status. *Aging Clinical and Experimental Research (Milano)*, *10*, 395-400.

Fisher, D., Li, C. M., Chiu, M. S., Themann, C. L., Petersen, H., Jonasson, F., . . . Cotch, M. F. (2014). Impairments in hearing and vision impact on mortality in older people: The AGES-Reykjavik Study. *Age and Ageing*, *43*, 69-76. doi:10.1093/ageing/aft122

Fried, T. R., Tinetti, M. E., & Iannone, L. (2011). Primary care clinicians' experiences with treatment decision making for older persons with multiple conditions. *Archives of Internal Medicine*, *171*, 75-80. doi:10.1001/archinternmed.2010.318

Genther, D. J., Betz, J., Pratt, S., Kritchevsky, S. B., Martin, K. R., Harris, T. B., . . . for the Health ABC Study. (2015). Association of hearing impairment and mortality in older adults. *The Journals of Gerontology, Series A: Biological Sciences & Medical Sciences*, *70*, 85-90. doi:10.1093/gerona/glu094

Hardy, S. E., Dubin, J. A., Holford, T. R., & Gill, T. M. (2005). Transitions between states of disability and independence among older persons. *American Journal of Epidemiology*, *161*, 575-584. doi:10.1093/aje/kwi083

Hart, P. M., Chakravarthy, U., Stevenson, M. R., & Jamison, J. Q. (1999). A vision specific functional index for use in patients with age related macular degeneration. *British Journal of Ophthalmology*, *83*, 1115-1120.

Heyl, V., & Wahl, H. W. (2012). Managing daily life with age-related sensory loss: Cognitive resources gain in importance. *Psychology and Aging*, *27*, 510-521. doi:10.1037/a0025471

Idler, E. L., & Benyamini, Y. (1997). Self-rated health and mortality: A review of twenty-seven community studies. *Journal of Health and Social Behavior*, *38*, 21-37.

Jacobs, J. M., Hammerman-Rozenberg, R., Maaravi, Y., Cohen, A., & Stessman, J. (2005). The impact of visual impairment on health, function and mortality. *Aging Clinical and Experimental Research*, *17*, 281-286.

Johnson, T., Rovner, B., & Haller, J. (2014). Suicide and visual loss: A case report reflecting the need for recognition and management in ophthalmological settings. *Seminars in Ophthalmology*, *29*, 202-204. doi:10.3109/08820538.2013.821500

Karpa, M. J., Gopinath, B., Beath, K., Rochtchina, E., Cumming, R. G., Wang, J. J., & Mitchell, P. (2010). Associations between hearing impairment and mortality risk in older persons: The Blue Mountains Hearing Study. *Annals of Epidemiology*, *20*, 452-459. doi:10.1016/j.annepidem.2010.03.011

Katz, S., Downs, T. D., Cash, H. R., & Grotz, R. C. (1970). Progress in development of the index of ADL. *The Gerontologist*, *10*, 20-30.

Kim, J. M., Stewart, R., Glozier, N., Prince, M., Kim, S. W., Yang, S. J., . . . Yoon, J. S. (2005). Physical health, depression and cognitive function as correlates of disability in an older Korean population. *International Journal of Geriatric Psychiatry*, *20*, 160-167. doi:10.1002/gps.1266

King, H., Aubert, R. E., & Herman, W. H. (1998). Global burden of diabetes, 1995-2025: Prevalence, numerical estimates, and projections. *Diabetes Care*, *21*, 1414-1431.

Laforge, R. G., Spector, W. D., & Sternberg, J. (1992). The relationship of vision and hearing impairment to one-year mortality and functional decline. *Journal of Aging and Health*, *4*, 126-148. doi:10.1177/089826439200400108

Lin, F. R., Yaffe, K., Xia, J., Xue, Q. L., Harris, T. B., Purchase-Helzner, E., . . . Simonsick, E. M. (2013). Hearing loss and cognitive decline in older adults. *JAMA Internal Medicine*, *173*, 293-299. doi:10.1001/jamainternmed.2013.1868

Lin, M. Y., Gutierrez, P. R., Stone, K. L., Yaffe, K., Ensrud, K. E., Fink, H. A., . . . Mangione, C. M. (2004). Vision impairment and combined vision and hearing impairment predict cognitive and functional decline in older women. *Journal of the American Geriatrics Society*, *52*, 1996-2002. doi:10.1111/j.1532-5415.2004.52554.x

Logsdon, R. G., Gibbons, L. E., McCurry, S. M., & Teri, L. (2002). Assessing quality of life in older adults with cognitive impairment. *Psychosomatic Medicine*, *64*, 510-519.

Marengoni, A., Angleman, S., Melis, R., Mangialasche, F., Karp, A., Garmen, A., . . . Fratiglioni, L. (2011). Aging with multimorbidity: A systematic review of the literature. *Ageing Research Reviews*, *10*, 430-439. doi:10.1016/j.arr.2011.03.003

McGee, D. L., Liao, Y., Cao, G., & Cooper, R. S. (1999). Self-reported health status and mortality in a multiethnic US cohort. *American Journal of Epidemiology*, *149*, 41-46.

McGuire, L. C., Ford, E. S., & Ajani, U. A. (2006). Cognitive functioning as a predictor of functional disability in later life. *The American Journal of Geriatric Psychiatry*, *14*, 36-42. doi:10.1097/01.JGP.0000192502.10692.d6

Melzer, D., Izmirlian, G., Leveille, S. G., & Guralnik, J. M. (2001). Educational differences in the prevalence of mobility disability in old age: The dynamics of incidence, mortality, and recovery. *The Journal of Gerontology, Series B: Psychological Sciences & Social Sciences*, *56*, S294-S301.

Mendes de Leon, C. F., Fillenbaum, G. G., Williams, C. S., Brock, D. B., Beckett, L. A., & Berkman, L. F. (1995). Functional disability among elderly blacks and whites in two diverse areas: The New Haven and North Carolina EPESE. Established Populations for the Epidemiologic Studies of the Elderly. *American Journal of Public Health*, *85*, 994-998.

Mulrow, C. D., Aguilar, C., Endicott, J. E., Velez, R., Tuley, M. R., Charlip, W. S., & Hill, J. A. (1990). Association between hearing impairment and the quality of life of elderly individuals. *Journal of the American Geriatrics Society*, *38*, 45-50.

Ostbye, T., Yarnall, K. S., Krause, K. M., Pollak, K. I., Gradison, M., & Michener, J. L. (2005). Is there time for management of patients with chronic diseases in primary care? *Annals of Family Medicine*, *3*, 209-214. doi:10.1370/afm.310

Parekh, A. K., Kronick, R., & Tavenner, M. (2014). Optimizing health for persons with multiple chronic conditions. *The Journal of the American Medical Association*, *312*, 1199-1200. doi:10.1001/jama.2014.10181

Pedone, C., Ercolani, S., Catani, M., Maggio, D., Ruggiero, C., Quartesan, R., . . . Cherubini, A. (2005). Elderly patients with cognitive impairment have a high risk for functional decline during hospitalization: The GIFA Study. *The Journal of Gerontology, Series A: Biological Sciences & Medical Sciences*, *60*, 1576-1580.

Peres, K., Verret, C., Alioum, A., & Barberger-Gateau, P. (2005). The disablement process: Factors associated with progression of disability and recovery in French elderly people. *Disability and Rehabilitation*, *27*, 263-276.

Pfeiffer, E. (1975). A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. *Journal of the American Geriatrics Society*, *23*, 433-441.

Reyes-Ortiz, C. A., Kuo, Y. F., DiNuzzo, A. R., Ray, L. A., Raji, M. A., & Markides, K. S. (2005). Near vision impairment predicts cognitive decline: Data from the Hispanic Established Populations for Epidemiologic Studies of the Elderly. *Journal of the American Geriatrics Society*, *53*, 681-686. doi:10.1111/j.1532-5415.2005.53219.x

Rudberg, M. A., Furner, S. E., Dunn, J. E., & Cassel, C. K. (1993). The relationship of visual and hearing impairments to disability: An analysis using the longitudinal study of aging. *Journal of Gerontology*, *48*(6), M261-M265.

Salive, M. E., Guralnik, J., Glynn, R. J., Christen, W., Wallace, R. B., & Ostfeld, A. M. (1994). Association of visual impairment with mobility and physical function. *Journal of the American Geriatrics Society*, *42*, 287-292.

Strawbridge, W. J., Wallhagen, M. I., Shema, S. J., & Kaplan, G. A. (2000). Negative consequences of hearing impairment in old age: A longitudinal analysis. *The Gerontologist*, *40*, 320-326.

Sullivan, M. (2003). The new subjective medicine: Taking the patient's point of view on health care and health. *Social Science & Medicine*, *56*, 1595-1604.

Swanson, M. W., & McGwin, G. (2004). Visual impairment and functional status from the 1995 National Health Interview Survey on Disability. *Ophthalmic Epidemiology*, *11*, 227-239. doi:10.1080/09286580490514540

Thielke, S., & Diehr, P. (2012). Transitions among health states using 12 measures of successful aging in men and women: Results from the Cardiovascular Health Study. *Journal of Aging Research, 2012*, Article 243263. doi:10.1155/2012/243263

Thompson, J. R., Gibson, J. M., & Jagger, C. (1989). The association between visual impairment and mortality in elderly people. *Age and Ageing*, *18*, 83-88.

Uhlmann, R. F., Larson, E. B., Koepsell, T. D., Rees, T. S., & Duckert, L. G. (1991). Visual impairment and cognitive dysfunction in Alzheimer's disease. *Journal of General Internal Medicine*, *6*, 126-132.

Van Eyken, E., Van Camp, G., & Van Laer, L. (2007). The complexity of age-related hearing impairment: Contributing environmental and genetic factors. *Audiology & Neurotology*, *12*, 345-358. doi:10.1159/000106478

West, S. K., Munoz, B., Rubin, G. S., Schein, O. D., Bandeen-Roche, K., Zeger, S., . . . Fried, L. P. (1997). Function and visual impairment in a population-based study of older adults: The SEE project. Salisbury Eye Evaluation. *Investigate Ophthalmology & Visual Science*, *38*(1), 72-82.

Whitson, H. E., Cousins, S. W., Burchett, B. M., Hybels, C. F., Pieper, C. F., & Cohen, H. J. (2007). The combined effect of visual impairment and cognitive impairment on disability in older people. *Journal of the American Geriatrics Society*, *55*, 885-891. doi:10.1111/j.1532-5415.2007.01093.x

Whitson, H. E., Malhotra, R., Chan, A., Matchar, D. B., & Ostbye, T. (2012). Comorbid visual and cognitive impairment: Relationship with disability status and self-rated health among older Singaporeans. *Asia-Pacific Journal of Public Health*, *26*, 310-319. doi:10.1177/1010539512443698

Wu, C. Y., Chou, Y. C., Huang, N., Chou, Y. J., Hu, H. Y., & Li, C. P. (2014). Cognitive impairment assessed at annual geriatric health examinations predicts mortality among the elderly. *Preventive Medicine*, *67*, 28-34. doi:10.1016/j.ypmed.2014.06.027

Yeung, P., Towers, A., La Grow, S., Philipp, M., Alpass, F., & Stephens, C. (2015). Mobility, satisfaction with functional capacity and perceived quality of life (PQOL) in older persons with self-reported visual impairment: The pathway between ability to get around and PQOL. *Disability and Rehabilitation*, *37*, 113-120. doi:10.3109/09638288.2014.910559